VASCULAR FLORA OF SALINE LAKES IN THE SOUTHERN HIGH PLAINS OF TEXAS AND EASTERN NEW MEXICO

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ABSTRACT

Saline lakes and freshwater playas form the principal surface hydrological feature of the High Plains of the Southern Great Plains. Saline lakes number less than 50 and historically functioned as discharge wetlands with relatively consistent water availability due to the presence of one or more springs. Currently, less than ten saline lakes contain functional springs. A survey of vascular plants at six saline lakes in the Southern High Plains of northwest Texas and one in eastern New Mexico during May and September 2009 resulted in a checklist of 49 species representing 16 families and 40 genera. The four families with the most species were Asteraceae (12), Amaranthaceae (8), Cyperaceae (5), and Poaceae (12). Non-native species (*Bromus catharticus*, *Poa compressa*, *Polypogon monspeliensis*, *Sonchus oleraceus*, *Kochia scoparia*, and *Tamarix ramosissima*) accounted for 10% of the total species recorded. Whereas nearly 350 species of vascular plants have been identified in playas in the Southern High Plains, saline lakes contain a fraction of this species richness. The Southern High Plains saline lake flora is regionally unique, containing taxa not found in playas, with species composition that is more similar to temperate desert wetlands of the Intermountain Region and Gulf Coastal Plain of North America.

RESUMEN

Los lagos salinos y las playas de agua dulce forman la principal superficie hidrológica de las High Plains de las Southern Great Plains. El número de lagos salinos es menor de 50 e históricamente funcionaron como humedales de descarga con relativa continuidad en la disponibilidad de agua debido a la presencia de uno o más surgencias. Actualmente, solo menos de diez lagos salados contienen surgencias activas. Se realizó un estudio de las plantas vasculares en seis lagos salinos en las Southern High Plains del noroeste de Texas y uno en el este de Nuevo México durante mayo y septiembre de 2009 que dio como resultado un catálogo de 49 especies que representan a 16 familias y 40 géneros. Las cuatro familias con mayor número de especies fueron Asteraceae (12), Amaranthaceae (8), Cyperaceae (5), y Poaceae (12). Las especies no-nativas (*Bromus catharticus*, *Poa compressa*, *Polypogon monspeliensis*, *Sonchus oleraceus*, *Kochia scoparia*, y *Tamarix ramosissima*) fueron el 10% del total de especies citadas. Mientras que se han Identificado cerca de 350 especies de plantas vasculares en las playas de las Southern High Plains, los lagos salinos contienen una fracción de esta riqueza en especies. La flora de los lagos salinos de las Southern High Plains es única regionalmente, contiene taxa no encontrados en playas, con una composición de especies que es más similar a los humedales de los desiertos templados de la región Intermontana y la llanura costera del golfo de Norte América.

INTRODUCTION

In the High Plains of the western Southern Great Plains, playa wetlands and saline lakes form the predominant hydrological surface features. This is particularly evident in the Southern High Plains (SHP) of northwest Texas and eastern New Mexico. Playas of the SHP have received a tremendous amount of conservation and management focus, primarily stemming from concerns regarding natural and anthropogenic threats to playa functional ecology and structure (Bolen et al. 1989; Haukos & Smith 1994; Luo et al. 1997; Smith 2003; Johnson et al. 2012). Numbering nearly 20,000, playas are shallow, isolated, freshwater, precipitation filled recharge wetlands which have been described as islands of biological diversity in one of the most intensively agriculturalized regions in North America (Bolen et al. 1989; Haukos & Smith 1994; Johnson et al. 2012). Playas are dy-

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namic and biologically productive wetlands that provide critical habitat for migrating, breeding, and wintering waterfowl (Ray et al. 2003; Haukos et al. 2006; Moon & Haukos 2006); migrating (Davis & Smith 1998) and breeding shorebirds (Conway et al. 2005a, b); and wintering sandhill cranes (*Grus canadensis*; Iverson et al. 1985). The playa flora has also been the focus of numerous studies, including checklists (Rowell 1971), field guides (Haukos & Smith 1997), and more detailed analyses of plant community structure as related to soils, playa area, and physical location on the landscape (Smith & Haukos 2002; Haukos & Smith 2004; O'Connell et al. 2012).

In contrast, saline lakes of the SHP are poorly studied, and have received little or no conservation attention. Despite the conservation focus upon playas, saline lakes are arguably the most imperiled wetland ecosystem in the region and have been identified as a High Priority Community within the High Plains Ecoregion (Texas Parks and Wildlife Department 2005). Approximately 1 saline lake exists for every 500 historical playas regionally (Reeves & Temple 1986; Haukos & Smith 1994; Smith 2003), but their numerical rarity makes them, and their associated biota, particularly susceptible to both natural and anthropogenic perturbations.

Saline lakes differ from playas ecologically, geologically, and hydrologically (Reeves & Temple 1986; Osterkamp & Wood 1987; Hall 2001). Saline lakes are generally larger than playas, have saline water chemistry, (>200 g/L of dissolved solids [Osterkamp & Wood 1987; Dockery 1989]), are often underlain by areas of deep Permian salt dissolution (Dockery 1989), and usually are bordered by dunes on their leeward side from deflation (Osterkamp & Wood 1987). Geologically older than playas (~300,000 ybp [Wood 2002]), most regional saline lakes have evidence of human occupation 10,000–12,000 ybp (E. Johnson, unpublished data).These settlements were likely due to the permanence of one or more freshwater springs connected to the Ogallala Aquifer in an environment with otherwise rare surface water. Still considered discharge wetlands, saline lakes currently receive most surface water via direct precipitation and from overland flow, as natural artesian freshwater springs associated with most saline lakes have ceased (or have dramatically reduced) flowing during the last 50 years (Brune 1981). Some evidence suggests that ground water elevation in saline lakes is at least 7–8 m lower than 25–55,000 ybp (Wood 2002). As such, surface water presence (and residence time) operates as an ecological driver of floral and faunal (e.g., bird and insect) community attributes in saline lakes (Conway et al. 2005 a, b; Andrei et al 2008; Conway unpublished data; Saalfeld et al. 2012).

Conservation concerns surrounding saline lakes are multifaceted, but cessation of spring flow causing a reduction in surface water residence time and an increase in salt concentrations are arguably the most pressing. Saline lake hydrology is impacted by interactions among variable hydroperiods, high evapotranspiration rates, unpredictable precipitation patterns, and anthropogenic disturbances (i.e., groundwater pumping; Conway et al. 2005a, b; Saalfeld et al. 2011, 2012). For example, when annual irrigation practices of groundwater pumping coincide with extended drought and surface water evaporation, surface water is very ephemeral. Predictions of increasing evaporation rates in models of future climate change will further reduce hydroperiods in saline lakes, which are considered to be at "regionally high risk" of alteration under current climate change models (Matthews 2008).

In saline lakes, rooted vascular plants are typically restricted to close proximity to remnant artesian spring discharge zones, leaving most of the basin floor without vegetation. Due to their inhospitable environments, saline lakes possess a fraction of the floral diversity of playas (Rowell 1971; Haukos & Smith 1997) and provide habitat for more specialized avian fauna than playas (Iverson et al. 1985; Conway et al. 2005 a, b; Andrei et al. 2008; Saalfeld et al. 2011, 2012). For saline lakes, much of the basic biological inventory and natural history data are lacking. The purpose of the research reported here is to provide an annotated checklist of vascular plants collected from accessible saline lakes in the SHP of Texas and eastern New Mexico.

METHODS

The SHP is an approximately 80,000 km^2 region occurring from the panhandle of Texas (south of the Canadian River), into New Mexico (east of the Pecos River), and south to Midland, Texas, at a regional elevation of approximately 1000 m (Osterkamp & Wood 1987). Level topography is broken by shallow freshwater playa wetlands; draws; and large, deep, saline lakes. Although playas numerically dominate, approximately 40 saline lakes also occur; and combined, these features comprise the regionally dominant wetland systems. Regional annual precipitation averages approximately 45 cm/yr, with annual evaporation exceeding 200 cm/yr, as summer temperatures may reach 40°C. Within saline lakes, temperatures fluctuate diurnally during summer, ranging from 7–54°C (Saalfeld et al. 2012). The growing season in the region ranges from 193–287 days (NRCS 2000).

We acquired access to seven individual SHP saline lakes (Fig. 1). Three on private lands (Mound Lake, Rich Lake, and Tahoka Lake) are considered to be the best remaining saline lakes (Saalfeld et al. 2011, 2012) as they maintain some surface water with seasonally functional artesian springs. An additional three lakes (Goose Lake, Paul's Lake, and White Lake) are located on the Muleshoe National Wildlife Refuge and possess less regular spring flow. Grulla Lake, on the Grulla National Wildlife Refuge, no longer contains flowing artesian springs. Processes by which these lakes have formed have been widely debated, but recent work, via core sampling of lake basins, indicates some basin sediments are more than 300,000 years old (Wood 2002). Most saline lakes contain aeolian deposited lunettes on the lee side of the basin, consisting of fine lacustrine sediments, deposited when saline lakes are dry (Wood 2002). As the basin floor of saline lakes were historically connected to the top of the Ogallala Aquifer, soils of the basin are typically hydric loamy lacustine deposits (NRCS 2000) in form, and in some instance may be greater than 30 m deep, reflecting some aeolian deoposition on basin floors during periods of extended dry conditions (Wood 2002). Soils surrounding artesian springs, in which we focused our floristic surveys, tend to be sandier and overlay the hydric loamy lacustrine soil mentioned above.

Collecting trips were made to these saline lakes (Table 1) in 2009 from May 25th-28th and again from September 18th-19th. For reasons mentioned, collecting was focused near artesian spring discharge zones within the lake basins that we were confident experienced current or historical seasonal flooding. A complete set of voucher specimens is housed at the University of Texas at Austin Plant Resources Center Herbarium (TEX).

RESULTS AND DISCUSSION

This research resulted in a collection of 49 species of vascular plants representing 16 families and 40 genera (Table 2). The four families with the most species were Asteraceae (12), Amaranthaceae (8), Cyperaceae (5), and Poaceae (12). Non-native species (*Bromus catharticus, Poa compressa, Polypogon monspeliensis, Sonchus oleraceus, Kochia scoparia*, and *Tamarix ramosissima*) accounted for 10% of the total species. Overall species richness within each lake, excluding Tahoka Lake, was poor, only ranging from 3–14 species (Table 1). Tahoka Lake contained 43 of the 49 species identified during the surveys, and 21 species that were not collected from any other saline lake (Table 2). Mound, Goose, and Grulla Lakes contained one unique species each, while Rich Lake contained three (Table 2). The only species common to all saline lakes was the exotic invasive *Tamarix ramosissima* (Table 2).

Reasons for disparities in species richness among saline lakes may be related to historical anthropogenic alterations and surrounding land use practices. Each saline lake is bordered by some combination of upland grasslands, row crop agriculture, or former cropland planted to exotic perennial grasses under the U.S. Department of Agriculture, Conservation Reserve Program. Row crop agriculture impacts local hydrology via groundwater pumping for irrigation. To date, no studies have been performed to estimate water use of these areas surrounding each basin. Nonetheless, Tahoka Lake remains the least impacted saline lake because no anthropogenic alterations nor any petrochemical exploration has occurred on the lake basin bottom (unlike Mound and Rich lakes). Tahoka Lake still contains three functional artesian springs, located at the north, west, and southwestern boundaries of the lake basin. Although spring flow is more intermittent now than in the past (Conway et al. 2005 a, b; Saalfeld et al. 2011, 2012), it maintains the plant richness reported herein. On its northeastern border, Mound Lake contains several small seeps and one dominant spring surrounded by a *Bolboschoenus maritimus* subsp. *paludosus* dominated marsh (Fig. 2). A long history of petrochemical development on the north and south sides of the lake have probably impacted other springs. Rich Lake contains only

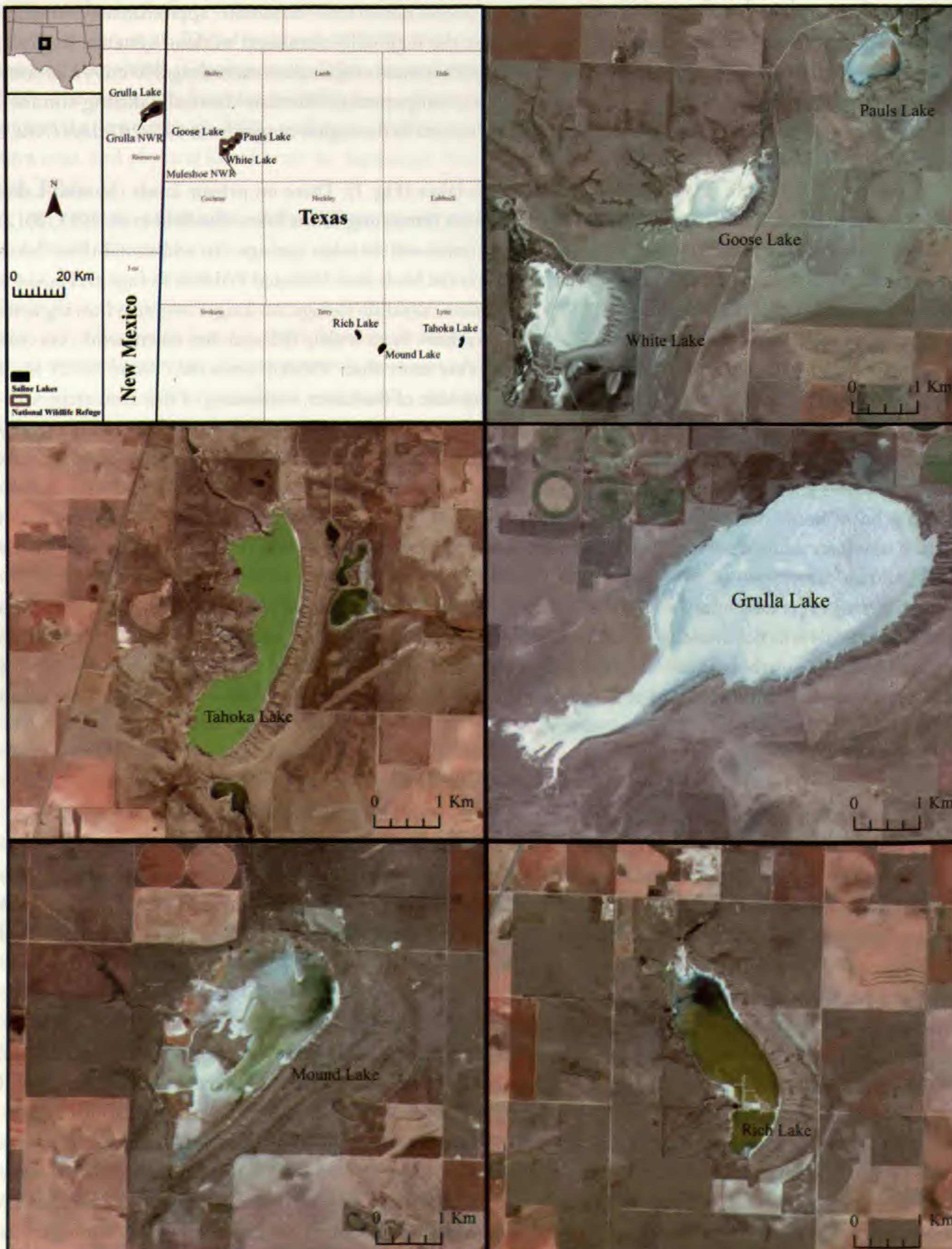

Fig. 1. Location and satellite imagery of saline lakes surveyed in the Southern High Plains of Texas and eastern New Mexico, May and September, 2009.

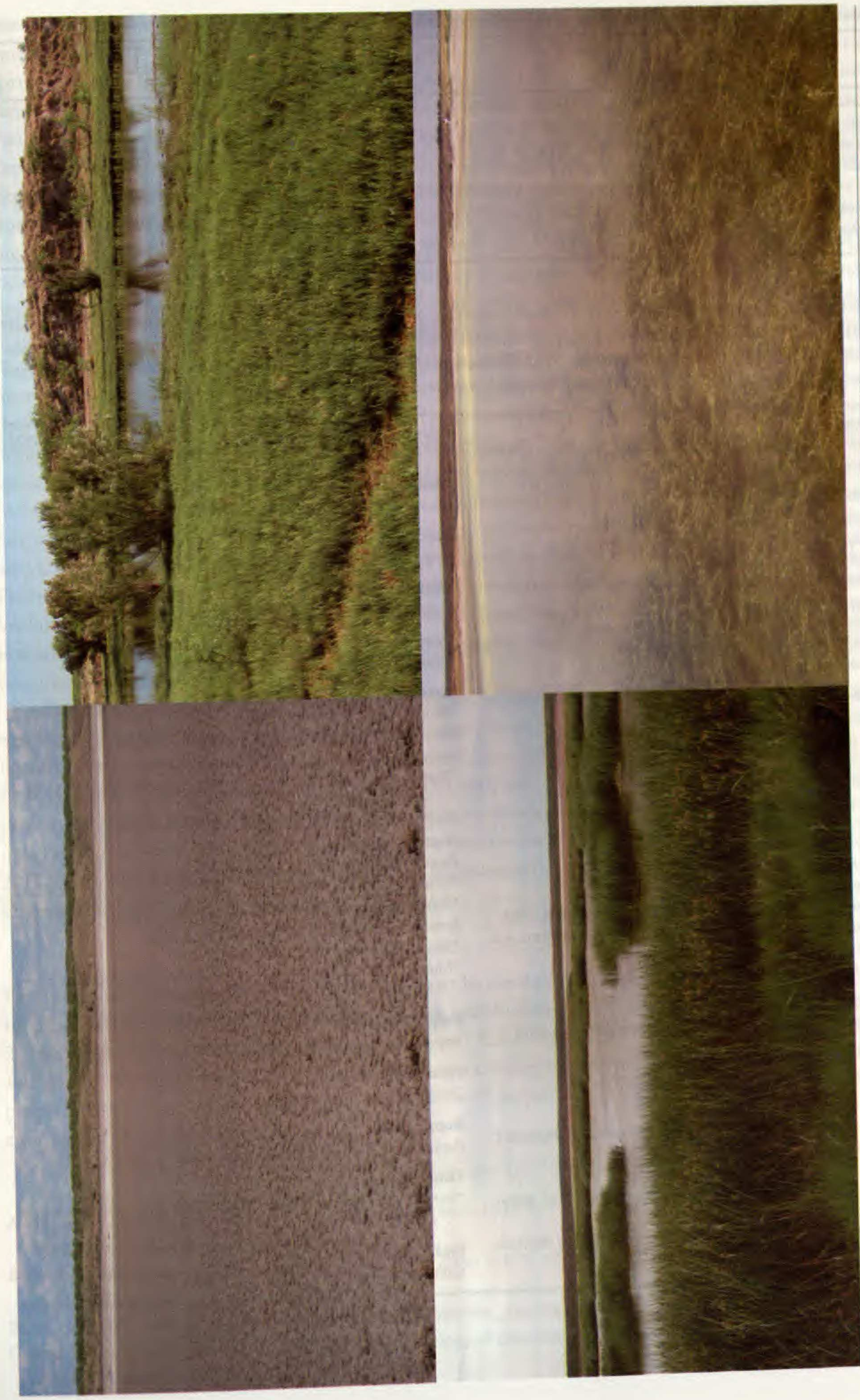

Fig. 2. Top left: General aspect of saline lakes of the SHP showing largely un-vegetated basin floor (Tahoka Lake). **Top right:** *Distichlis spicata* meadow, Tahoka Lake. **Bottom left:** *Bolboschoenus maritimus* subsp. *paludosus* marsh (with *D. spicata* in the foreground), Mound Lake. **Bottom right:** Submerged bed of *Ruppia maritima*, White Lake.

Table 1. Size, location, and species richness of saline lakes surveyed in the Southern High Plains of Texas and eastern New Mexico, May and September, 2009.

	Size (ha)	Lat/Lon	County, State	Richness
Goose Lake (G)	90	33° 57′ 37″ N 102° 44′ 37″ W	Bailey Co., TX	4
Grulla (Gr)	875	34° 5′ 23″ N 103° 4′ 27″ W	Roosevelt Co., NM	3
Mound Lake (M)	600	33° 13′ 42″ N 102° 4′ 52″ W	Terry Co., TX	14
Paul's Lake (P)	70	33° 58′ 47″ N 102° 43′ 11″ W	Baily Co., TX	10
Rich (R)	270	33° 16′ 37″ N 102° 11′ 46″ W	Terry Co., TX	10
Tahoka Lake (T)	285	33° 14′ 58″ N 101° 44′ 49″ W	Lynn Co., TX	43
White Lake (W)	135	33° 56′ 33″ N 102° 46′ 7″ W	Baily Co., TX	6

Table 2. Checklist of the vascular flora saline lakes surveyed in the Southern High Plains of Texas and eastern New Mexico, May and September, 2009. (Goose Lake = **G**, Grulla Lake = **Gr**, Mound Lake = **M**, Paul's Lake = **P**, Rich Lake = **R**, Tahoka Lake = **T**, and White Lake = **W**). Collection numbers are the first author's. Non-native species are indicated by an asterisk (*) based on review of Correll & Johnston (1970). Species not recorded from playas are indicated by superscript dagger (†) based on review of Rowell (1971), Smith & Haukos (2002), and Haukos & Smith (1997).

Aizoaceae

†*Sesuvium verrucosum* Raf., **GGrPRTW** 4897, 4926, 4943, 4948, 4953, 4957

Amaranthaceae

†*Atriplex canescens* (Pursh) Nutt., **MT** 4927, 4972
†*Atriplex subspicata* (Nutt.) Rydb., **T** 4988
Chenopodium berlandieri Moq., **T** 4986
Kochia scoparia* (L.) Schrad., **MPTW 4987, 5004, 5009, 5011
†*Salicornia rubra* A. Nelson, **Gr** 4947
†*Suaeda depressa* (Pursh) S. Watson, **MT** 4998, 4999
†*Suaeda nigra* (Raf.) J.F. Macbr., **TP** 4990, 5010
†*Suaeda suffrutescens* S. Watson, **T** 4975

Asteraceae

†*Ambrosia confertiflora* DC., **MT** 4982, 5002
Baccharis salicina Torr. & A. Gray, **MT** 4976, 5001
Conyza canadensis (L.) Cronquist, **T** 4983
Grindelia ciliata (Nutt.) Spreng., **T** 4985
†*Grindelia nuda* Alph. Wood var. *nuda*, **T** 4994
Helianthus petiolaris Nutt., **T** 4991
Machaeranthera tanacetifolia (Kunth) Nees, **T** 4984
Pluchea purpurascens (Sw.) DC., **MT** 4979, 5003
Sonchus oleraceus* L., **M 4922
Symphyotrichum divaricatum (Nutt.) G.L. Nesom, **MT** 4978, 5005
†*Xanthisma spinulosum* (Pursh) D.R. Morgan & R.L. Hartm. var. *spinulosum*, **R** 4936
Xanthium strumarium L., **T** 4997

Boraginaceae

Heliotropium curassavicum L. var. *curassavicum*, **TP** 4899, 5012

Convolvulaceae

†*Cressa truxillensis* Kunth, **GPTW** 4894, 4941, 4954, 4958

Cyperaceae

Bolboschoenus maritimus L. (Palla) subsp. *paludosus* (A. Nelson) T. Koyama, **MPRT** 4909, 4925, 4933, 4945
†*Eleocharis rostellata* (Torr.) Torr., **T** 4896
Schoenoplectus americanus (Pers.) Volkart ex Schinz & R. Keller, **T** 4910
†*Schoenoplectus pungens* (Vahl) Palla var. *longispicatus* (Britton) S.G. Sm., **RT** 4915, 4934
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla, **PMT** 4923, 4944, 4962

Gentianaceae

†*Eustoma exaltatum* (L.) Salisb. ex G. Don, **T** 4996

Juncaceae

Juncus torreyi Coville, **T** 4960

Malvaceae

Malvella leprosa (Ortega) Krapov., **G** s.n.

Onagraceae

†*Gaura parviflora* Douglas ex Lehm., **T** 4992

Poaceae

Bromus catharticus* Vahl, **R 4935
Distichlis spicata (L.) Greene, **MPRT** 4898, 4924, 4931, 4940
Elymus canadensis L. var. *canadensis*, **T** 4959
†*Elymus elymoides* (Raf.) Swezey subsp. *brevifolius* (J.G. Sm.) Barkworth, **R** 4937
Hordeum jubatum L. subsp. *jubatum*, **PRT** 4913, 4932, 4946
Hordeum pusillum Nutt., **T** 4906
Panicum obtusum Kunth, **T** 4993
*†*Poa compressa* L., **T** 4901
Polypogon monspeliensis* (L.) Desf., **RT 4902, 4930
Sporobolus airoides (Torr.) Torr., **TW** 4971, 5008
†*Sporobolus texanus* Vasey, **MT** 4980, 5000
†*Tridens muticus* (Torr.) Nash var. *elongatus* (Buckley) Shinners, **T** 4905

Polygonaceae

Polygonum ramosissimum Michx., **T** 4989

Potomogetonaceae

Zannichellia palustris L., **T** 4908

Ruppiaceae

Ruppia maritima L., **PTW** 4907, 4939, 5007

Tamaricaceae

Tamarix ramosissima* Ledeb., **GGrMPRTW 4895, 4926, and sight records

Typhaceae

Typha domingensis Pers., **MT** 4974, 5006 one primary spring on the northwestern margin of the basin, now dominated by *Tamarix ramosissima*, and extensive alteration (i.e., dikes and levees) on its southern side. Grulla Lake no longer has any functional springs, and had the poorest richness found in this study. Two Muleshoe NWR Lakes (Goose and White) also have very intermittent springs, where discharge occurs only during the early growing season. Conversely, Paul's Lake has remained flooded for an extended period of time, as removal of *T. ramosissima* in this basin has apparently allowed spring flow to recover. However, all three Muleshoe saline lakes contain an elevated levee partitioning each lake. Constructed as Work Projects Administration (WPA) projects to improve water retention in a portion of each basin, these levees have dramatically altered water flow in each lake, effectively creating two different systems within each basin; one with some spring flow, the other without. As no rooted plants exist on any saline lake basin, except in close proximity to artesian springs, the floral richness among lakes reflects the importance of maintaining springs and minimizing impacts to individual lake basin hydrology.

Saline lakes contain slightly more than 10% of the species richness of playas (approximately 350 species [Rowell 1971; Haukos & Smith 1997; Haukos & Smith 2004]). Nineteen species collected from saline lakes have not been reported from playas (Table 2). Dominant species of the saline lakes we surveyed are similar to those described for temperate desert wetlands of the Intermountain Region of Western North America and occur in well defined zones in response to topographic gradients (West & Young 2000). We observed *Distichlis spicata* to form a "meadow" in seasonally saturated to very shallowly flooded soils. Whereas an emergent marsh of *Bolboschoenus maritimus* subsp. *paludosus* or submerged "beds" of *Ruppia maritima* occur where surface water is deeper and persists longer (Fig. 2). These species (and a few interstitial species in our checklist) are also known to be important members of saltmarsh communities of the temperate and tropical Gulf Coastal Plain. Two other species we recorded, *Suaeda nigra* and *Sporobolus airoides*, are listed as important members of lowland salt-desert shrub communities of all four North American deserts (West & Young 2000). More work is needed to better understand the floristic relatedness of saline lakes of the SHP to other halophytic plant communities of North America.

This survey represents the first attempt to characterize saline lake flora of the SHP of northwest Texas and eastern New Mexico. Since the survey in 2009, the region has been experiencing an extended drought, which has at least temporarily altered the flora in some of these lakes, Tahoka Lake in particular. Reductions in spring flow, even in these saline lakes that maintain some artesian flow, combined with little or no precipitation, may permanently alter this distinctive regional flora. These wetlands are unique systems and provide virtually the only nesting habitat for snowy plovers (*Charadrius nivosus*) in the region (Conway et al. 2005 a, b; Saalfeld et al. 2011, 2012). This survey provides further evidence of the importance of freshwater spring conservation in SHP saline lakes.

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